A TDMA BROADCAST SATELLITE / GROUND ARCHITECTURE FOR THE AERONAUTICAL TELECOMMUNICATIONS NETWORK

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Project

- The work here was done as part of the Advanced Communications for **Air Traffic Management Project at NASA Glenn Research Center in Cleveland, Ohio**

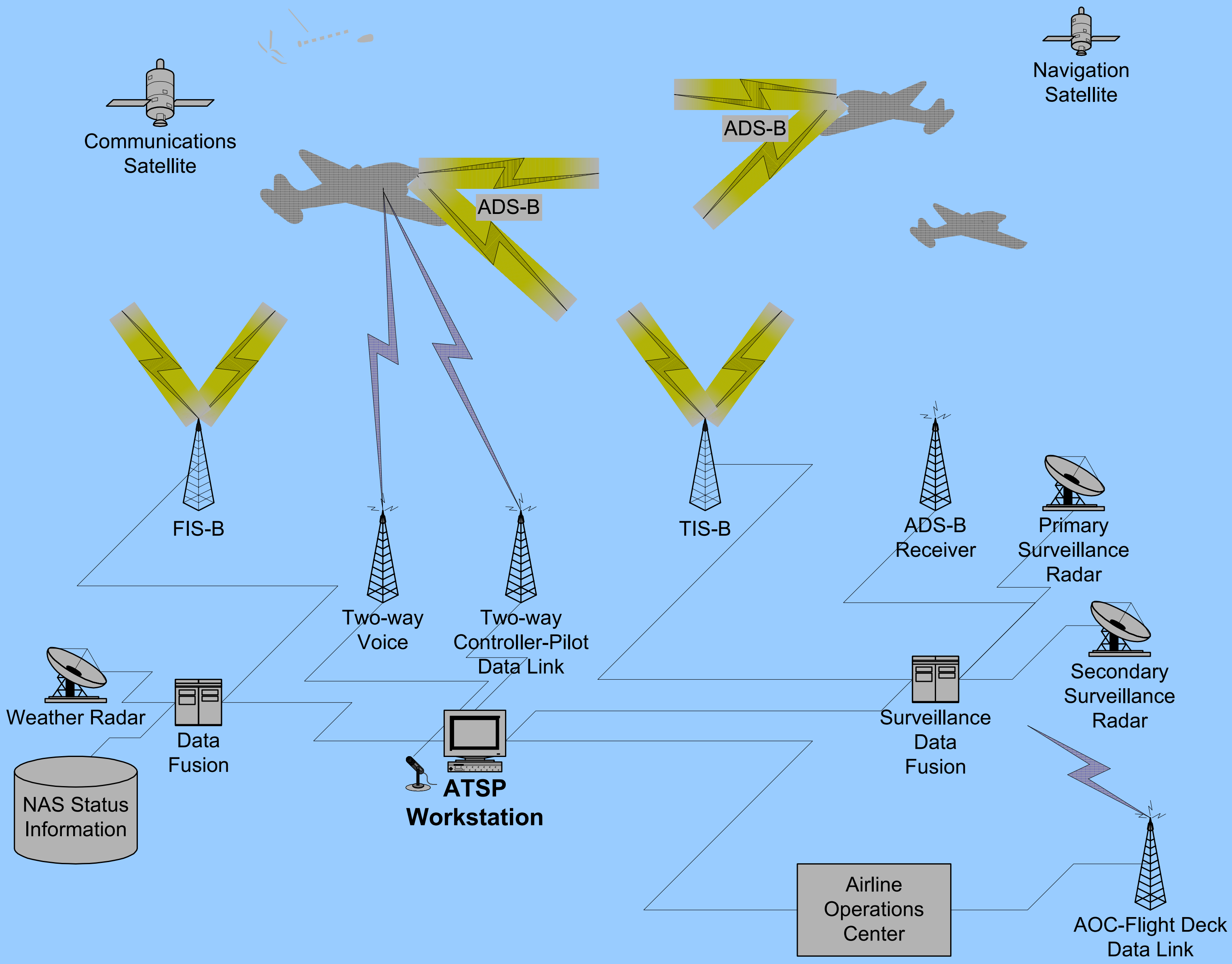
Satellite Communications for Air Traffic Management

- Different architectures that involve satellite system usage:
  - Use SatCom as a primary
  - Use SatCom as an integral sub-component
  - Use SatCom as a backup

Broadcast Satellite ATM Architecture

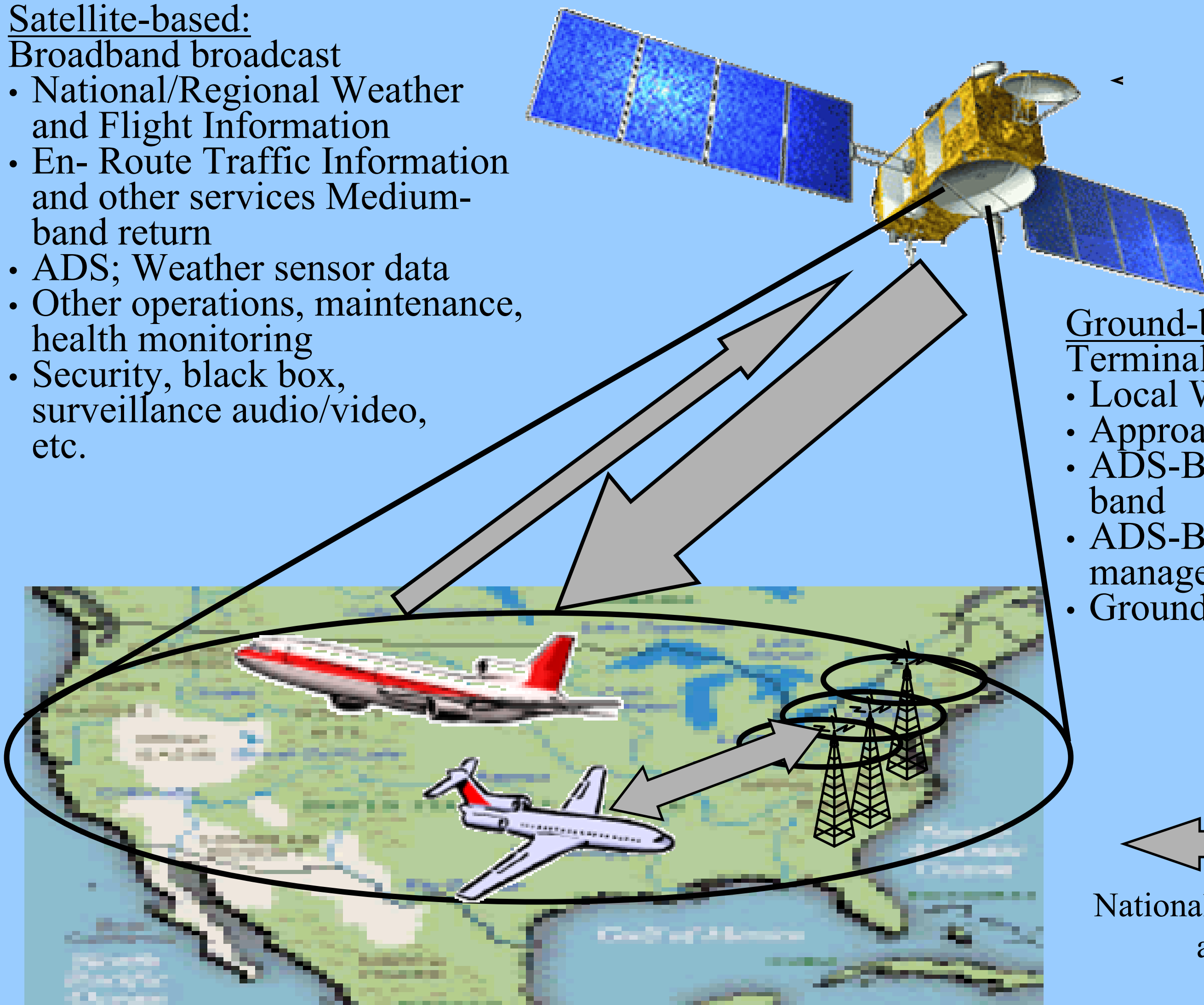
- Broadcast TIS-B and FIS-B via Geostationary satellite
- Broadcast other information and applications if and when they arise
- A sub-component type of architecture that will still rely heavily on a ground architecture to handle at minimum
  - ADS-B
  - CPDLC
  - Voice
  - Possible backup for satellite

ATM Components



Future Satellite Subnetwork

<u>Satellite-based:</u>
Broadband broadcast
- National/Regional Weather and Flight Information
- En- Route Traffic Information and other services Medium-band return
- ADS; Weather sensor data
- Other operations, maintenance, health monitoring
- Security, black box, surveillance audio/video, etc.



<u>Ground-based:</u>
Terminal area broadband:
- Local Wx, FIS, TIS
- Approach/departure
- ADS-B Surface medium-band
- ADS-B round traffic management
- Ground ops clearances, etc.

National/Global Interoperbility
and Networking

The Ground Components of the broadcast Architecture

- A ground based network is needed along with the Satellite system for:
  - ADS-B ground stations which listen to ADS-B transmissions from aircraft sent via the Mode S and Universal Access Transceiver (UAT) data links.
  - tracking from primary and secondary surveillance radars.
  - VHF Digital Link Mode 2, 3 or 4 transceivers for the reception and transmissions of Controller-Pilot Data Link Communications (CPDLC) messages and for voice.

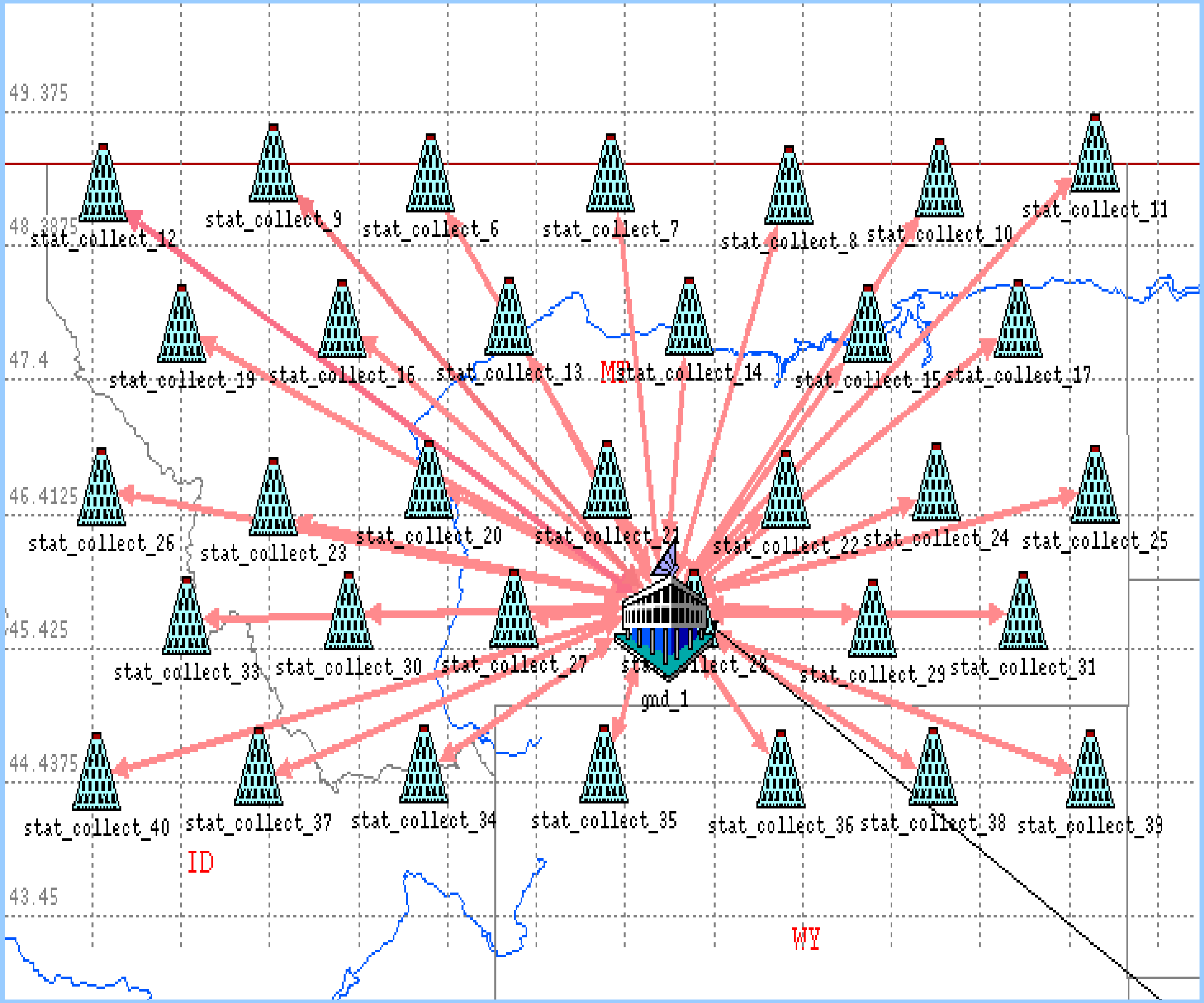
The Ground Components of the broadcast Architecture (continued)

- The ground-based ADS-B listening stations, and the primary, en-route, and secondary surveillance radar sites feed their information to TIS-B ground stations

- TIS-B ground stations process the incoming data to remove redundant information.

- The TIS-B ground stations then uplink filtered data to aircraft via a satellite network to provide a complete situational awareness picture to aircraft equipped to receive TIS-B information

The Ground Components of the broadcast Architecture (continued)



The Ground Components of the broadcast Architecture (continued)

- Redundant data needs to be removed for the following reasons:

  – ADS-B transmissions from the same aircraft may be heard by more than one listening station in the ground-based network. However, that information should be relayed via satellite only once.

  – Even when an aircraft broadcasts ADS data, it is probably being tracked by ground-based radars as well (except in remote areas.) The satellite ground stations should only uplink whichever data is collected that is of a higher quality.

The Ground Components of the broadcast Architecture (continued)

- ADS-B traffic is generated at the intervals specified for individual aircraft in RTCA DO-260A, the 1090 MHz Extended Squitter MOPS
- packets transmitted are 112 bit Mode S packets chosen for convenience. ADS-B and TIS-B information relayed to the satellite ground stations are likely to be Mode S Extended Squitters.
  - Although different packet formats may be used within the SATCOM network, current experiment the Mode S format was retained because each satellite ground station will still need to relay the 56 bit ADS-B payload, as well as the 24 bit ICAO address. Therefore Using a 112 bit packet allows for four bytes of header information, at least

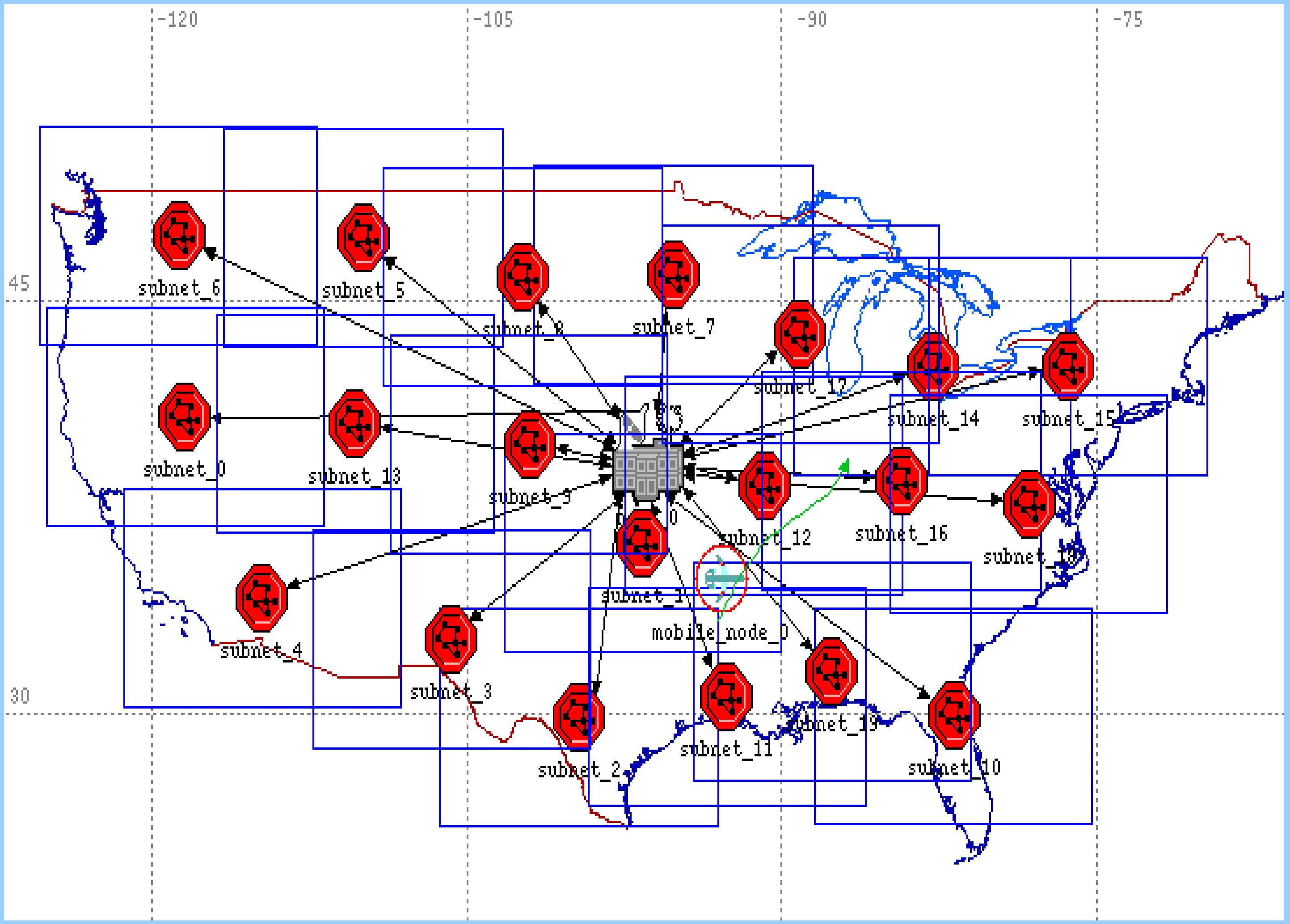
The Ground Components of the broadcast Architecture (continued)

- Aircrafts using either Mode S, or UAT, but not both. An external source (the satellite network) is needed to provide data about aircraft using the other data link.
- TIS-B is needed about aircraft which are not transmitting ADS-B information at all. This group of aircraft are only seen by ground-based radar.
- TIS-B for areas beyond regional will allow better flight planning and Free Maneuvering decision making
- The range of ADS-B is limited by the transmitter power of the sending aircraft, and by the interference environment present
- FIS-B will be available for a wide area to each aircraft
- The regional centers ATCC in turn, forward the collected information to one or more satellite uplink ground stations preferably collocated at ATCC.
- Multiple satellite uplinks may be used to combat the effects of local weather disturbances on the uplink transmissions. Downlink to aircraft will not be as affected

The Satellite Component of the Broadcast Architecture

- A broadcast satellite based system:
  - mainly dedicated for the transmission of surveillance data (TIS-B) as well as En-route Flight Information Service Broadcast (FIS-B) to all aircraft.
  - Other applications that may be available at time of launch.
  - Consists of Satellite in Geo Orbit located at W101 deg for the purpose of this architecture to serve the CONUS
  - Ground earth stations 20 located at ATCC preferably although not required
    - Each of the ground stations will be transmitting a burst of messages at a TDMA rate of 0.01 second time slots with a 0.005 guard band. Hence for 20 stations we are able to receive a TIS-B or a FIS-B faster than the minimum required rate of 1 per second. Note the time slots can be increased five fold
  - (receive only) Satellite Receivers on the Aircrafts

The Satellite Component of the Broadcast Architecture (Continued)



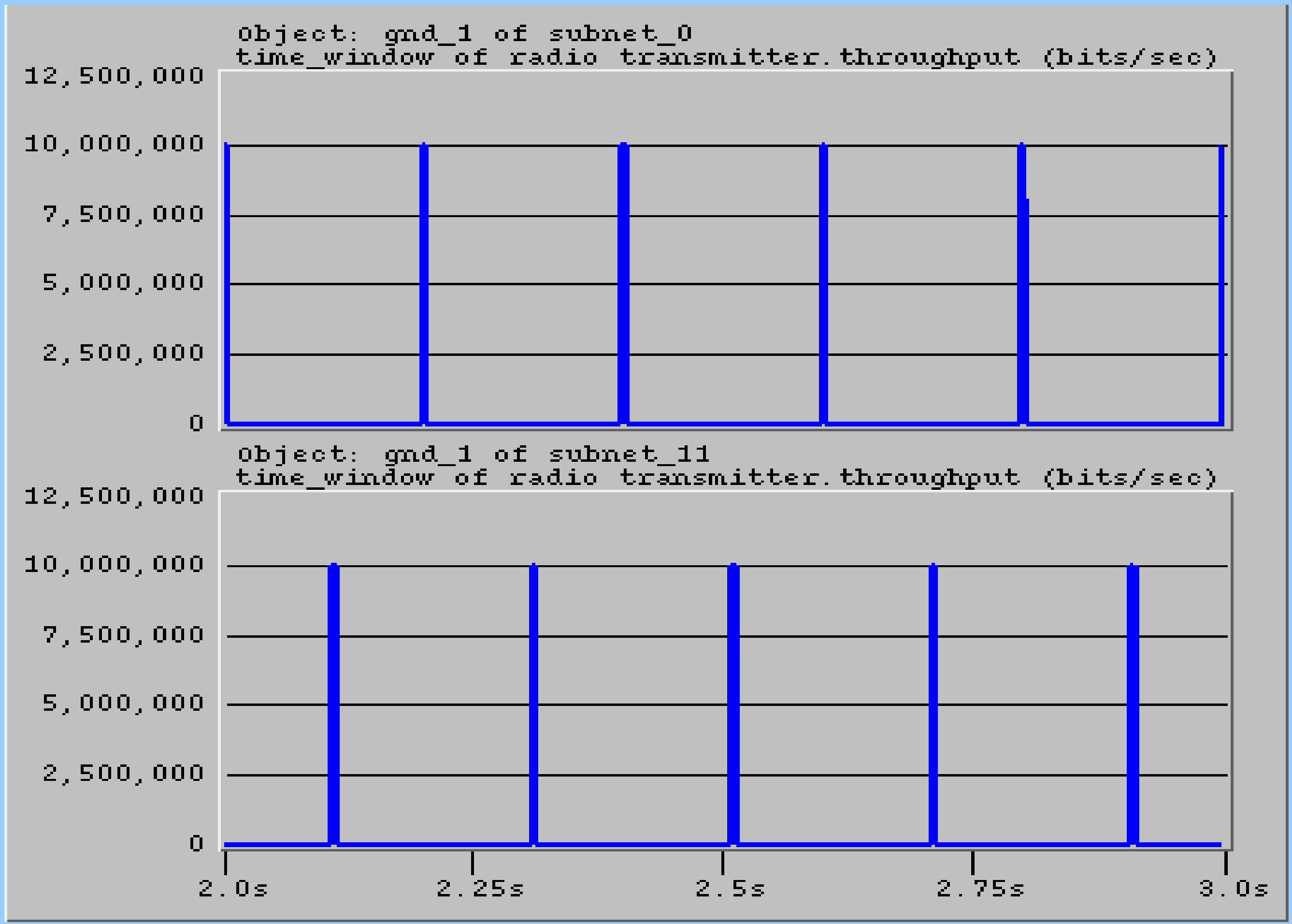
The Satellite Component of the Broadcast Architecture (Continued)

Uplink Frequency (GHz)	29.750
Downlink Frequency (GHz)	19.95
GSO Satellite Transponder Parameters	
Uplink xponder saturation flux density (dBW/m^2)	-96
Xponder saturation EIRP (dBW)	54
Uplink receive G/T (dB/K)	13.9
Uplink receive noise temp (K)	575.44
Uplink receive gain (dBi)	41.50000047
Satellite Altitude (km)	35786
ATC Hub Station Parameters	
Antenna diameter (m)	2.4
Xmit gain (dBi)	55.26205892
Xmit power (dBW)	17 (50.12 watts)
Xmit EIRP (dBW)	72.26205892
Recv gain (dBi)	51.79117752
System Noise Temp (dB-K)	26.67 (464.52 K)
Recv G/T (dB/K)	25.12117752
Elevation angle to satellite (deg)	40
Aircraft Terminal Parameters	
Recv gain (dBi)	37
System Noise Temp (dB-K)	25 (316.23 K)
Recv G/T (dB/K)	12
Elevation angle to satellite (deg)	40
Signal Modulation/Coding Parameters	
Hub source data rate (Rb) (bps)	10000000
Channel symbol rate Rs (sps)(1/2 coding & QPSK)	10000000
Required (10-6 @ 1/2 ,K=7 FER, QPSK)	4.5
Bandwidth-limited Capacity of Xponder	
Xponder BW (Hz)	27000000
User Xmit BW (Hz)	20000000

Brdcst Grnd-Aircraft Lnk Bdgt Final results	
UPLINK factors	
Hub Elevation Angle(deg)	40
Coverage Angle (deg)	13.30864957
Central Angle (deg)	43.34567522
Slant Range to Sat (km)	37780.30419
Free-Space Path Loss (dB)	-213.4628304
Atmospheric Loss (dB)	-0.461666838
Rain Loss (dB) 99.90 % availabili	-14.56591541
Polarization Loss (dB)	-1
Received U/L C/No (dB-Hz)	85.2728554
DOWNLINK factors	
Slant Range to Sat (km)	37780.30419
Free-Space Path Loss (dB)	-209.991949
Atmospheric Loss (dB)	-0.447838163
Polarization Loss (dB)	-1
A/C Noise Temp	316.23 K
Recv Downlink C/No (dB-Hz)	79.41685937
NET LINK PERFORMANCE	
Net C/No (dB-Hz)	78.41433558
Available Eb/No (dB)	7.414335582
Require 10-6;QPSK; r=1/2 conv cc	4.5
Link Margin at Hub (dB)	2.914335582

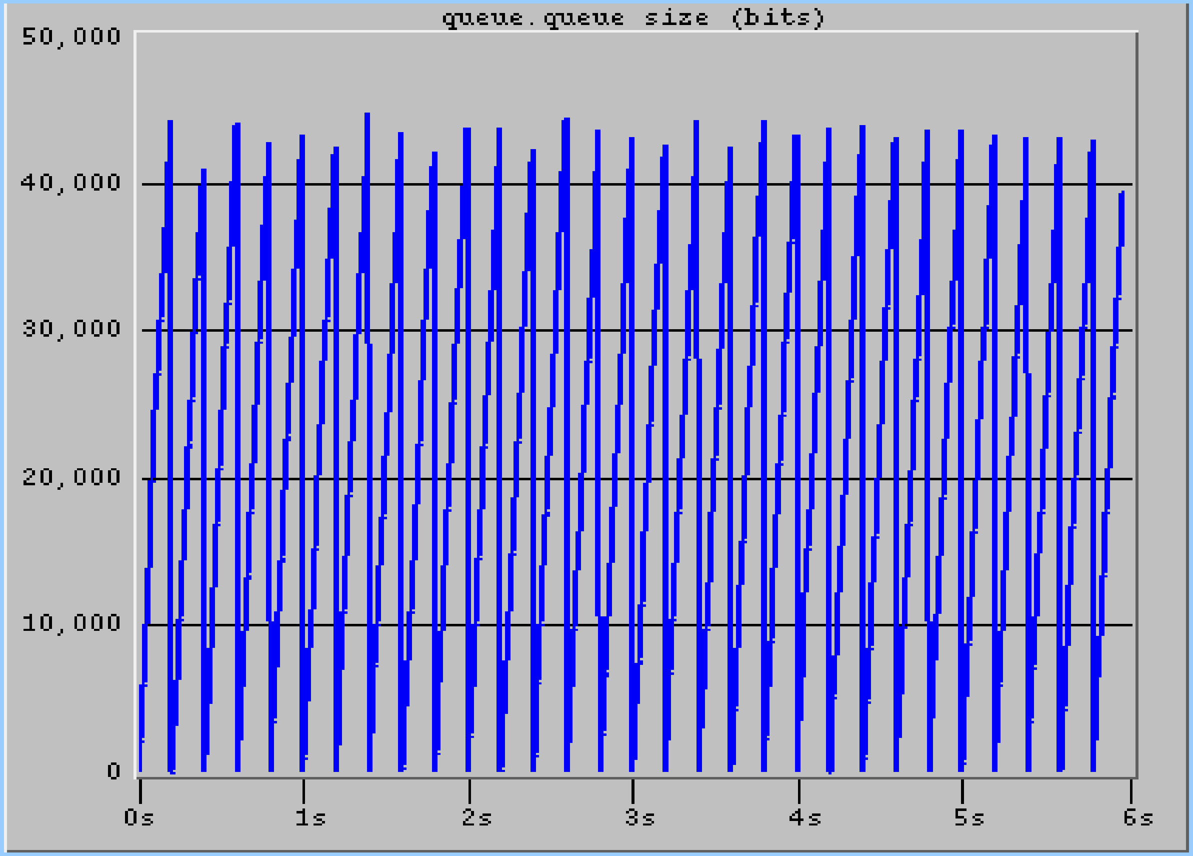
Modeling and Simulations

TDMA Transmissions for two different satellite ground stations



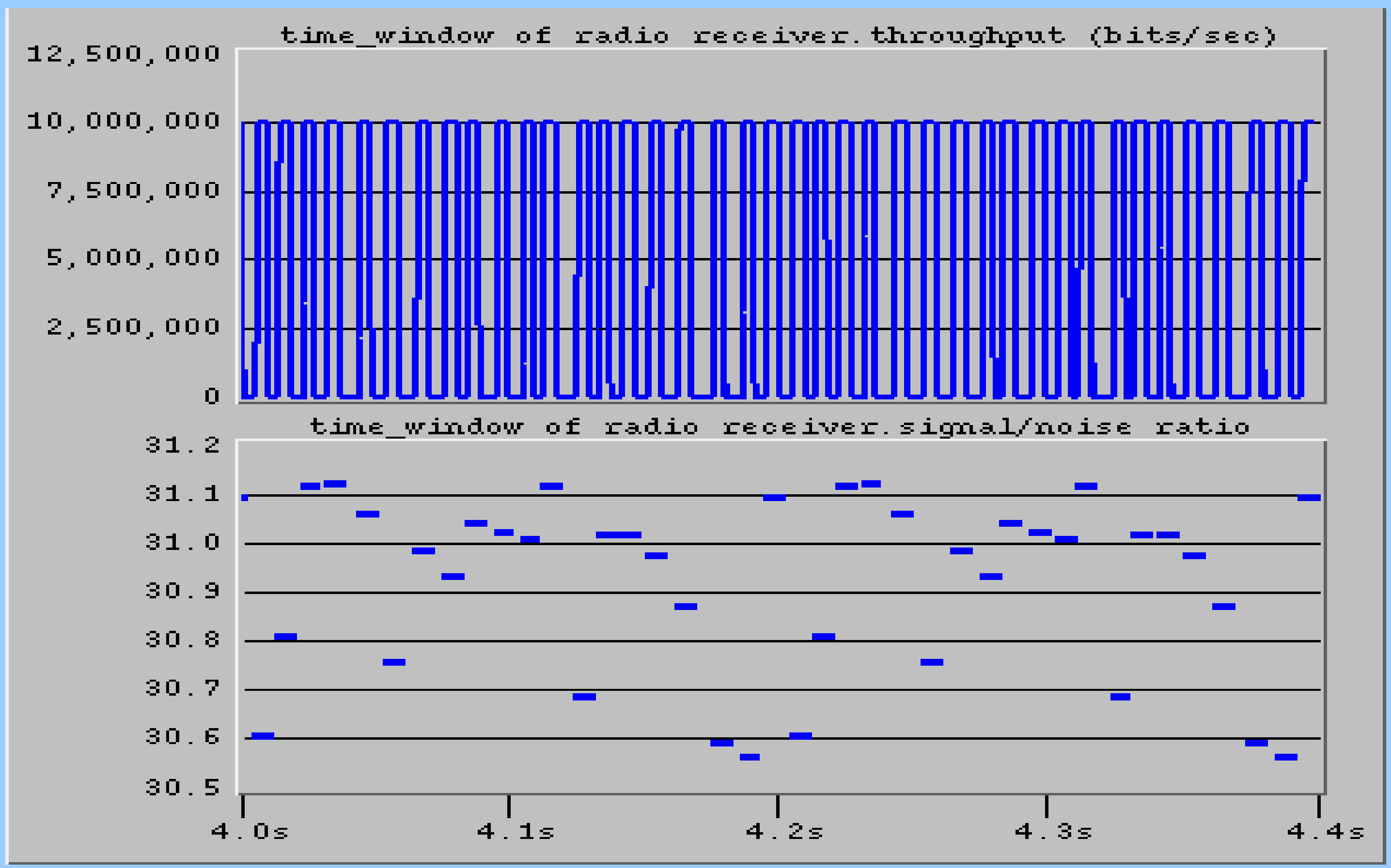
Modeling and Simulations (Continued)

Queue build up and empty operation at a ground station transmitter



Modeling and Simulations (Continued)

Satellite received signal (from all ground stations)



Conclusions

- Use of satellite links for the transmission and broadcasting of TIS-B and FIS-B messages was proposed as an alternative to ground based proposals
- The architecture uses ground ADS-B mode S, and UAT transceivers, and secondary and primary surveillance radars, all for transmission of ADS-B, and present radar operations.
- Satellite transponder is used in a bent pipe method along with satellite ground stations. The satellite earth stations collect ADS-B and radar information from all the aircraft within its sector, filter the data to remove redundancies and create TIS-B and FIS-B messages to broadcast to aircrafts equipped with Sat receivers.
- Modeling and Simulations as well as link budget analyses were done to study system

Advantages of Broadcast Architecture

- Broadcast capability to wide areas
- Use of possibly existing satellite leased transponders
- The reception only for the aircraft simplifies and reduces the cost of the aircraft equipment
- Having TIS-B, and FIS-B data readily available about any area (or within CONUS for a non-global design) is beneficial for the airlines, FAA, and pilots in making flight plans, free flight, and scheduling.
- The satellite links are reliable for En Route
- With two transponders on the satellite each at a different frequency, it would be possible to support 660 aircraft per ARTCC, with TDMA slots of 0.02 seconds, with one transponder handling eastern traffic, and the other handling western traffic as an option.
- In addition to FIS-B.
- redundancy can be achieved by using other satellite transponders
- The use of the ground part of this architecture conforms with the accepted standards that are proposing VDL, Mode S and radar for the various communications and navigations services for the ATN
- Number of ground stations and accessing schemes can be upgraded
- A reasonable approach for an initial design. System can be upgraded to a full up uplink/downlink in future, given spot beams over each ground station area already present (does require aircraft sat transmitters in addition to receivers).
- More applications can be added, such as broadcast voice, alert messages, other.

Disadvantages of Broadcast Architecture

- For other than en-route traffic, at altitudes below cloud level there is a higher probability of signal loss due to weather. Backup ground broadcast at local congested regions may be necessary
- Oceanic regions still have to transmit their ADS-B data via links that could be scarce such as HF, or a different operator of satellite. More equipment is then necessary. Data for oceanic can also be gotten via possible relay methods if proposed.
- Antennas that are capable of steering are necessary for higher gains and data rates.
- Can not uplink any data from aircrafts directly